AD 740855

AFCRL-72-0173
6 MARCH 1972
ENVIRONMENTAL RESEARCH PAPERS, NO. 391

AIR FORCE CAMBRIDGE RESEARCH LABORATORIES

L. G. HANSCOM FIELD, BEDFORD, MASSACHUSETTS

Climatology as a Function of Map Type

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AIR FORCE SYSTEMS COMMAND

United States Air Force

Unclassified
Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)
Air Force Cambridge Research Laboratories (LKI)
L.G. Hanscom Field
Bedford, Massachusetts 01730

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP

3. REPORT TITLE

CLIMATOLOGY AS A FUNCTION OF MAP TYPE

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)
Scientific. Interim.

5. AUTHOR(S) (First name, middle initial, last name)

Iver A. Lund

6. REPORT DATE
6 March 1972

7a. TOTAL NO OF PAGES
21

7b. NO. OF REFS
7

8a. CONTRACT OR GRANT NO.

b. PROJECT, TASK, WORK UNIT NOS. 8624-02-01

c. DOD ELEMENT 62101F

d. DOD SUBELEMENT 681000

9a. ORIGINATOR'S REPORT NUMBER(S)
AFCRL-72-0173

9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)
ERP No. 391

10. DISTRIBUTION STATEMENT

Approved for public release; distribution unlimited.

11. SUPPLEMENTARY NOTES

TECH, OTHER

12. SPONSORING MILITARY ACTIVITY
Air Force Cambridge Research Laboratories (LKI)
L.G. Hanscom Field
Bedford, Massachusetts 01730

13. ABSTRACT

Four sets of eight objectively produced map types were generated for use in estimating the probability of four six-hourly precipitation categories observed at Travis AFB, California. Daily precipitation probability forecasts were prepared for 585 winter days using ten different procedures. All four sets of map types yield six-hour precipitation forecasts that are better than unconditional climatology, but none of them yield as much information as climatology conditioned on past six-hourly precipitation. Climatology conditioned on both past precipitation and map type is the best.

DD FORM 1 NOV 65 1473

Unclassified
Security Classification

Unclassified

Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Meteorology Weather forecasting Objective forecast studies Weather map types Map-pattern classification Correlation						

Unclassified

Security Classification

Abstract

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1. INTRODUCTION

A map-pattern classification method that is suitable for use on high-speed computers was developed by Lund (1963). After a few rather arbitrary decisions, the method is completely objective. The decisions involve such matters as the size of the geographical area, location of the observation points, threshold value of the correlation coefficient, and data sample. The method is sufficiently general to permit classifying multiple events whether or not they can be depicted on a map. The only requirement is that the events be expressed numerically.

In common with other methods, many variations of the procedure are possible. The purpose of this paper is to explore some of these variations. Other variations have already been examined by Godske (1965), Bjorem (1966), Augulis (1969), Hartranft, Restivo and Sabin (1970a, 1970b) and others.

In this study four variations of the 1963 procedure were used to develop sets of map types for the purpose of determining the "best" variation. The first variation closely paralleled the procedure described in the 1963 article; the maps were classified without regard to the current, or subsequent weather, and a single map was used as a type. The second variation resembled the first except the map types were averages of a number of similar maps. The third and fourth variations were the

(Received for publication 1 March 1972)

same as the first and second, respectively, except the data were stratified according to the subsequent weather before the map types were developed. The variations will be illustrated with an example in the following sections.

2. PROBLEM

The problem was to develop a forecast aid to estimate the probability of four categories of future six-hourly precipitation amount at Travis Air Force Base, California, in winter. It was assumed that either an 0400 LST synoptic chart, or an accurate prognostic chart valid at 0400 LST, of the 1000-mb surface would be available for use in preparing the probability estimates of subsequent precipitation categories.

3. PREDICTAND

The daily total amount of precipitation observed during the six-hour period between 0400 LST and 1000 LST was divided into the four categories shown in Table 1. (The following abbreviations will be used throughout this paper: LT = less than; LE = less than or equal to; GT = greater than; and GE = greater than or equal to.) The data sample consisted of 585 days from the months of December, January and February between December 1963 and February 1970. Data for 47 of the 632 possible days were not used because 1000-mb data were not available.

Table 1. The Four Precipitation Categories and the 1000 LST Relative Frequency of Occurrence (Estimate of the Probability) of Each

Category	Precipitation (P)	Frequency (Cases)
A	P = 0.00	67.9% (397)
B	P = Trace	13.2% (77)
C	P GE 0.01 LE 0.10	11.1% (65)
D	P GT 0.10	7.9% (46)

4. CONDITIONAL CLIMATOLOGY

Table 2 shows the relative frequency of occurrence (estimate of the probability) of each six-hourly precipitation category reported at 1000 LST as a function of the category reported at 0400 LST, six hours earlier. All categories tend to recur much more frequently than expected from the unconditional climatology.

Table 2. The Conditional Relative Frequency of Occurrence (Estimate of the Probability) of Each Six-Hourly Precipitation Category Reported at 1000 LST as a Function of the Category Reported at 0400 LST, Six Hours Earlier. The unconditional relative frequencies (from Table 1) are shown in parenthesis

		Category at Subsequent Hour (1000 LST)				Sample Size
Category		A	B	C	D	(N)
at	A	85(68)	9	4	2	421
Initial	B	34	43(13)	17	6	53
Hour	C	26	19	30(11)	26	70
(0400 LST)	D	7	7	41	44(8)	41
Sample Size	(N)	397	77	65	46	585

5. PREDICTOR DATA

The 0400 LST geopotential height of the 1000-mb surface was available for each of the 13 grid-points shown in Figure 1 for the 585 days. These data were used in developing the map types.

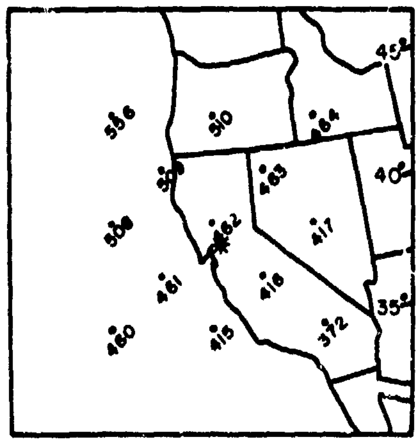

Figure 1. Location of Grid Points. The asterisk marks the location of Travis AFB, California

6. MAP-PATTERN CLASSIFICATION

The four variations of the map-pattern classification procedure discussed in the introduction were used to develop sets of map types to determine the "best" aid for estimating subsequent precipitation categories at Travis AFB. These variations are described in the following four sub-sections.

6.1 General Types

The 1000-mb geopotential height maps were classified without regard to the current, or subsequent weather, and a single most representative map was used for a particular type. Map types were selected by the following procedure:

Step 1. The 1000-mb heights at the 13 grid-points shown in Figure 1 on each map were correlated with the corresponding heights on the other 584 maps in the data sample. This yielded 584 correlation coefficients for each map.

Step 2. The map having the largest number of correlation coefficients GE 0.90 was designated as Type I.

Step 3. Those maps having a correlation coefficient of GE 0.90 with the Type I map selected in Step 2 were removed from the sample. Type II was then selected from the remaining maps as in Steps 1 and 2.

Step 4. The above process was repeated until only a few cases with correlation coefficients GE 0.90 with any one map remained in the sample.

There were 85 maps whose correlation coefficient with the map of 8 February 1969 was GE 0.90. Since this was more than any other map, 8 February 1969 was selected as Type I. After the 85 maps designated Type I were removed from consideration, there remained 53 maps in the sample whose correlation coefficient with the map of 4 December 1969 was GE 0.90. The map for this date was selected as Type II. The process of removing the appropriate maps and counting the correlation coefficients GE 0.90 was continued until eight types were selected. The map types are shown in Figure 2, and Table 3 gives the 1000-mb geopotential heights associated with each type, the date of the map chosen as a type, and the number of maps highly correlated with that type.

Table 3. The 1000-mb Geopotential Heights (Meters) Associated With Each of the General Map Types

Grid Point	General Map Type							
	I	II	III	IV	V	VI	VII	VIII
372	169	116	123	224	158	112	133	139
415	169	138	139	226	163	149	173	154
416	176	134	163	242	146	123	144	160
417	183	137	222	286	125	82	113	190
460	131	189	182	210	155	194	183	210
461	139	170	173	232	140	171	169	197
462	151	164	190	253	119	151	147	199
463	153	167	238	284	100	125	112	230
464	168	167	281	312	95	71	91	261
508	72	197	197	202	121	202	159	251
509	67	197	199	230	85	174	135	248
510	78	198	229	253	62	148	108	258
556	46	216	208	183	59	181	118	267
Date	8 Feb'69	4 Dec'69	20 Feb'70	10 Jan'67	29 Dec'64	22 Feb'65	15 Jan'69	2 Feb'64
Cases GE 0.90	85	53	53	42	39	31	30	22

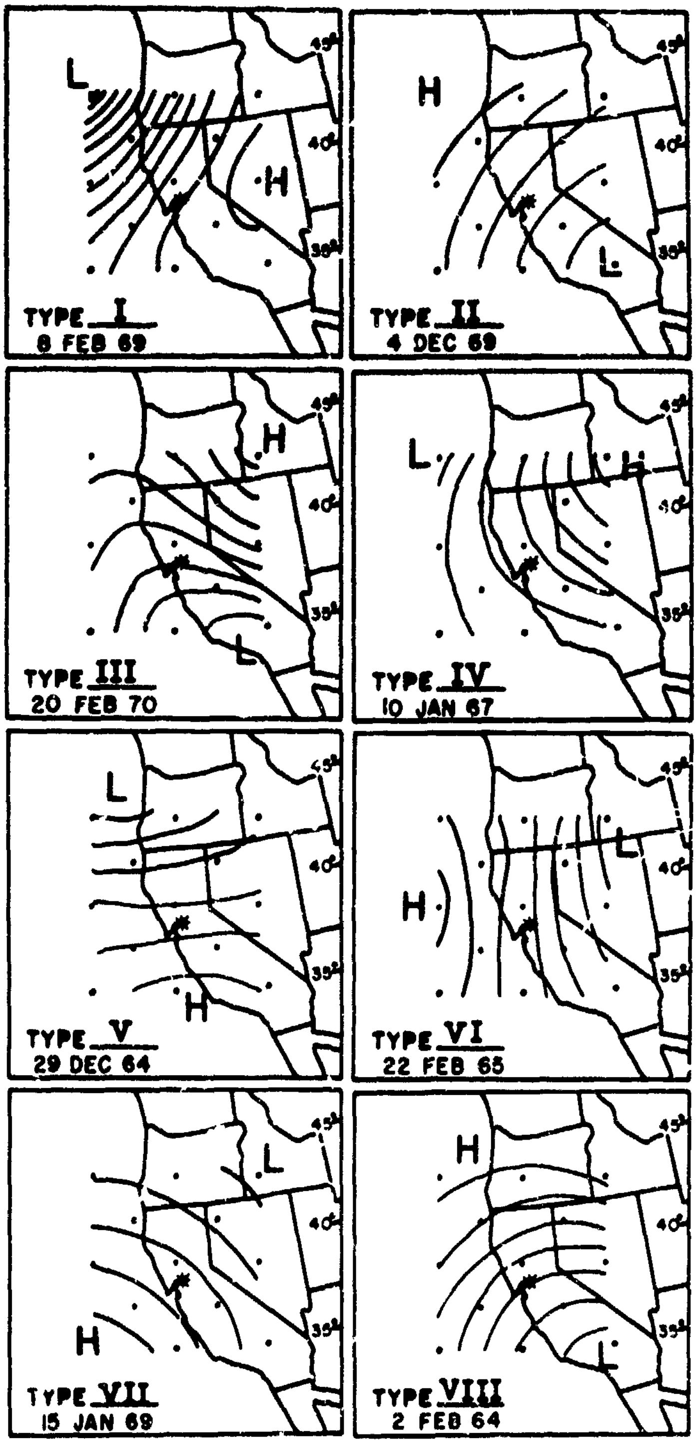

Figure 2. General Map Types Selected by the 1963 Procedure, Shown in the Order of Selection

6.2 Smooth General Types

The second set of map types were developed by selecting the first map in the same manner as described above. However, after the first map was selected, all maps with a correlation coefficient GE 0.90 with the map selected were averaged to obtain what was termed a smooth general type. There were 85 maps highly correlated (GE 0.90) with the map of 8 February 1969, Type I. The 1000-mb heights at each grid-point on each of these 85 maps were averaged, resulting in (smooth general) Type 1. (It will be noted that Roman numerals are used to identify the "general" map types and Arabic numerals to identify the "smooth general" types.) The map of average grid-point heights comprising Type 1 was correlated with the 585 other maps, and all maps with coefficients GE 0.90 were classified as Type 1 and removed from the data sample. The next map with the highest number of correlation coefficients GE 0.90 with the remaining maps was the map of 4 December 1969. It will be noted that this map is the same map selected as Type II, but it could have been different since the procedure resulting in Type 1 did not eliminate exactly the same maps as that used to select Type I. All maps highly correlated with the 4 December 1969 map were averaged to obtain Type 2. The Type 2 cases were removed from the sample and the process continued until eight "smooth general" types were developed. Figure 3 depicts the smooth general map types.

6.3 Stratified Types

The map typing procedure followed in developing stratified map types was the same as described in subsection 8.1 except that, before the procedure was begun, the maps were divided into four parts based upon the subsequent precipitation. Part A consisted of all the 0400 LST maps preceding precipitation category A, no precipitation. Likewise, Parts B, C and D were maps preceding precipitation categories B, C and D. In an effort to keep the number of types constant for each variation and to overcome small sample sizes in some cases, only two types were identified with each of the four precipitation categories. Figure 4 depicts the stratified map types.

6.4 Smooth Stratified Types

The procedure followed in developing smooth stratified map types was the same as described in subsection 6.2 except the maps were divided into four parts, as described in subsection 6.3, before the maps were typed. Again, only two smooth stratified types were identified with each of the four precipitation categories. They are shown in Figure 5.

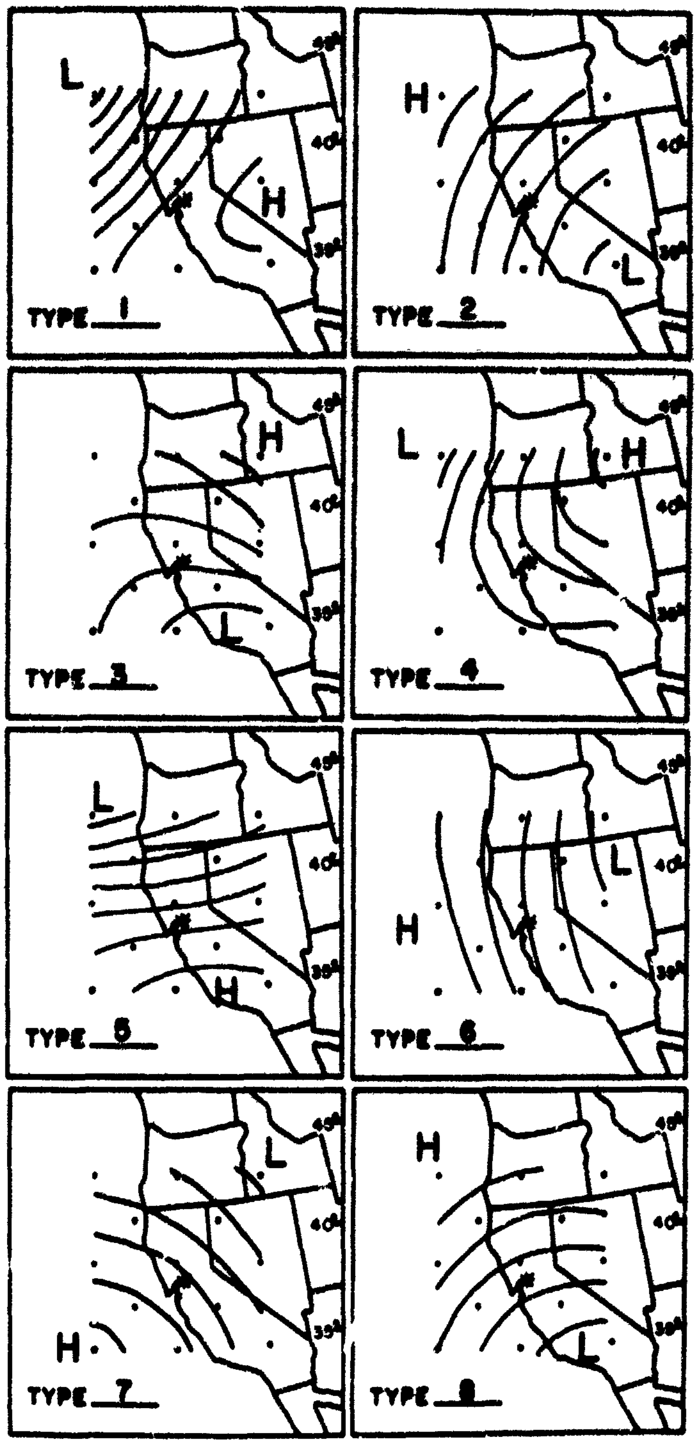

Figure 3. Smooth General Map Types Resulting From Averaging All Highly Correlated (Coefficient GE 0.90) Maps, Shown in the Order of Selection

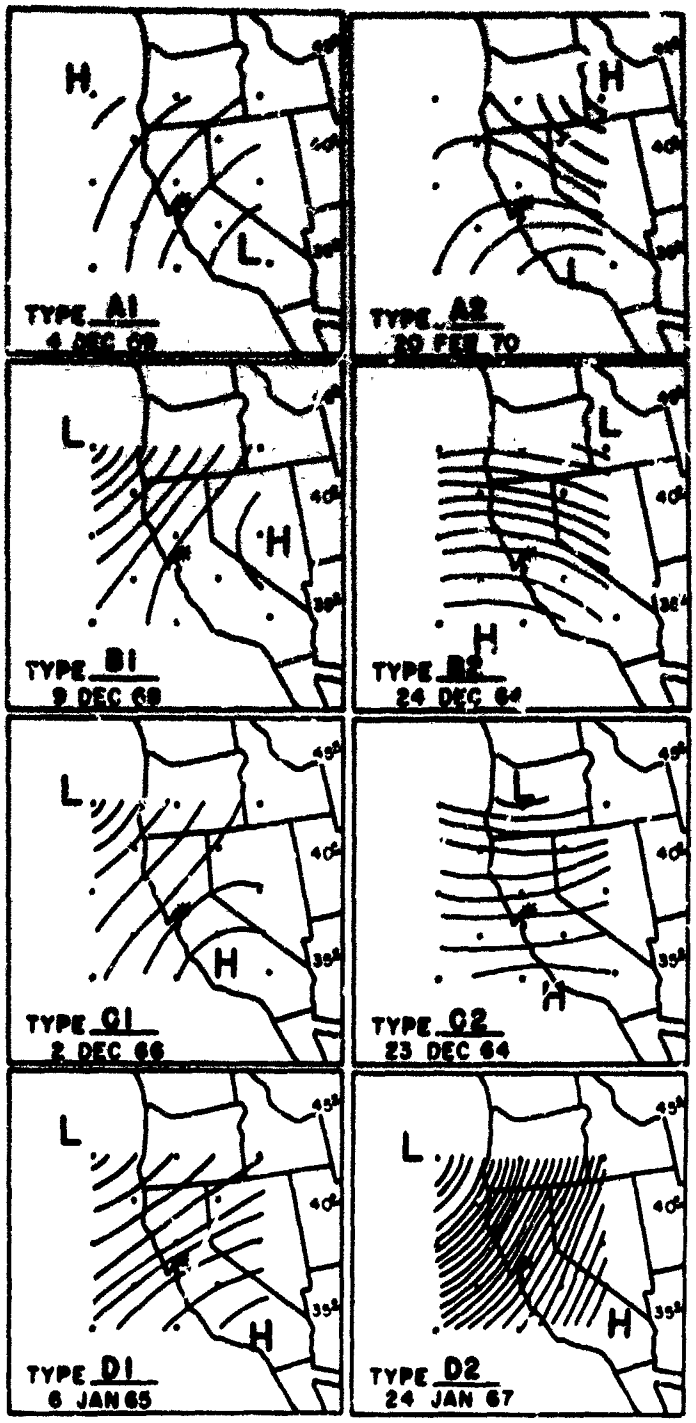

Figure 4. Stratified Map Types Selected by the 1963 Procedure After the Maps Were Stratified According to the Subsequent Precipitation Category, Shown in the Order of Selection

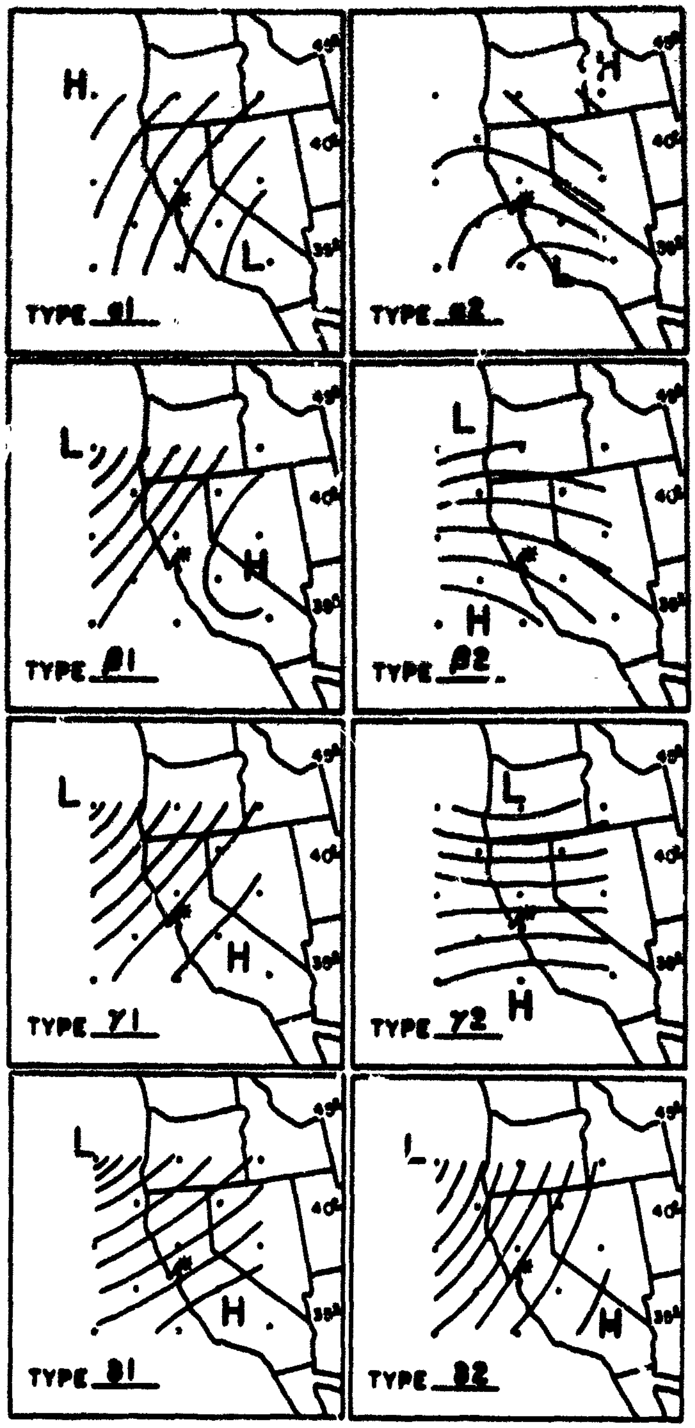

Figure 5. Smooth Stratified Map Types Resulting From Averaging All Highly Correlated (Coefficient GE 0.90) Maps Preceding the Same Precipitation Category, Shown in the Order of Selection

7. FORECASTING PROCEDURES

To evaluate the variations in map-pattern classification, forecasts of the probabilities of 0400-1000 LST precipitation amounts at Travis AFB were made using the following ten different procedures:

(1) Forecasts of precipitation category probabilities were made based on straight climatology. That is, the estimated probabilities of categories A, B, C and D given in Table 1 were forecast for every day in the study.

(2) Forecasts were made based on conditional climatology. That is, depending on the precipitation category at 0400 LST on a particular day, the appropriate estimated probabilities of categories A, B, C and D given in Table 2 were used.

(3) Each of the 585 sets of grid-point geopotential heights (maps) were correlated with the corresponding heights, given in Table 3, associated with each of the general map types. Each map (with the exception of 58 maps not correlated by a value GE 0.70 with any of the types) was assigned to the type with which it was most highly correlated. The relative frequencies of subsequent precipitation categories A, B, C and D associated with map types I through VIII were determined from the 585 day sample. They are shown in Table 4. Probability forecasts were prepared for each day with the probabilities governed by the 0400 LST general map type. For example, when Type I was observed at 0400 LST the following percent probabilities of subsequent precipitation categories A, B, C and D were predicted: 40, 16, 24 and 20 respectively.

Table 4. The Relative Frequency of Occurrence (Estimate of the Probability) of Each 1000 LST Precipitation Category as a Function of the 0400 LST General Map Type

General Map Type at 0400 LST	Precipitation Category at 1000 LST				Sample Size
	A(0.00)	B(Trace)	C(LE 0.10)	D(GT 0.10)	
I	40	16	24	20	112
II	96	3	1	0	70
III	84	13	4	0	79
IV	72	22	6	0	67
V	24	17	29	29	58
VI	82	14	4	0	51
VII	71	20	8	2	51
VIII	92	5	0	3	39
K*	74	5	12	9	58

*Map type K consists of all maps with a correlation coefficient LT 0.70 with all of the other types.

(4) Forecasts were made based on a precipitation climatology related to smooth general Types (1-8) as in (3) above.

(5) Forecasts were made based on a precipitation climatology related to stratified Types (A1 - D2) as in (3) above.

(6) Forecasts were made based on a precipitation climatology related to smooth stratified Types (α1 - δ2) as in (3) above.

(7) Forecasts were made based on a precipitation climatology related to both the precipitation category reported and the general Type (I - VIII) in existence at 0400 LST. That is, the relative frequencies (estimated probabilities) of subsequent precipitation categories A, B, C and D associated with 0400 LST precipitation categories A, B, C and D and Map Types I through VIII were determined and used as the forecast. Table 5 shows the relative frequencies determined from the 585 day sample. Line 1 shows, for example, that following the 61 days when the six-hourly precipitation reported at 0400 LST was 0.00 and the 0400 LST map type was I, subsequent precipitation categories A, B, C and D occurred 61, 18, 18 and 3 percent of the time, respectively.

(8) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and smooth general type as in (7) above.

(9) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and stratified type as in (7) above.

(10) Forecasts were made based on a precipitation climatology related to both the existing precipitation category and smooth stratified type as in (7) above.

Tables 4 and 5 show relative frequencies as functions of general map types. Similar tables were prepared for the stratified types and the smooth types but they are not shown.

8. VERIFICATION

Brier's (1950) "P" score was used to verify the forecasts of probability estimates of six-hourly precipitation categories for the ten different forecast procedures. The "P" score is expressed:

$$P = \frac{1}{N} \sum_{j=1}^{r} \sum_{i=1}^{N} (f_{ij} - E_{ij})^2$$

where in this case:

Table 5. The Relative Frequency of Occurrence (Estimate of the Probability) of Each 1000 LST Precipitation Category as a Function of the Precipitation Reported at 0400 LST and the 0400 LST General Map Type

Precipitation at 0400 LST	General Map Type at 0400 LST	Precipitation Category at 1000 LST				Sample Size
		A(0.00)	B(Trace)	C(LE 0.10)	D(GT 0.10)	
0.00	I	61	18	18	3	61
"	II	98	2	0	0	64
"	III	90	9	1	0	70
"	IV	82	16	2	0	56
"	V	47	21	11	21	19
"	VI	95	5	0	0	41
"	VII	83	14	3	0	29
"	VIII	95	3	0	3	37
"	K*	95	0	5	0	44
Trace	I	33	47	13	7	15
"	II	60	20	20	0	5
"	III	17	67	17	0	6
"	IV	33	50	17	0	6
"	V	25	0	25	50	4
"	VI	33	67	0	0	6
"	VII	40	40	20	0	5
"	VIII	50	50	0	0	2
"	K*	25	25	50	0	4
LE 0.10	I	13	0	37	50	24
"	II	100	0	0	0	1
"	III	100	0	0	0	1
"	IV	0	60	40	0	5
"	V	24	24	29	24	17
"	VI	33	0	67	0	3
"	VII	62	31	8	0	13
"	VIII	0	0	0	0	0
"	K*	0	33	33	33	6
GT 0.10	I	0	0	42	58	12
"	II	0	0	0	0	0
"	III	50	0	50	0	2
"	IV	0	0	0	0	0
"	V	0	11	50	39	18
"	VI	0	100	0	0	1
"	VII	50	0	25	25	4
"	VIII	0	0	0	0	0
"	K*	0	0	25	75	4

*Map type K consists of all maps with a correlation coefficient LT 0.70 with all of the other types.

N = the number of forecasts made using a particular procedure = 585

r = the number of precipitation categories = 4

f_{ij} = probability of precipitation category j forecast on the i^{th} forecast

E_{ij} = 1 if the 1000 LST precipitation was in category j and 0 if not.

Table 6 gives the "P" scores for the ten forecast procedures.

Table 6. "P" Scores Resulting From Applying Each of Ten Forecast Procedures

Set	Forecast Procedure	"P" Score
1.	Climatology	0.504
2.	Conditional climatology	0.385
3.	General types	0.426
4.	Smooth general types	0.425
5.	Stratified types	0.411
6.	Smooth stratified types	0.411
7.	Initial plus general	0.330
8.	Initial plus smooth general	0.326
9.	Initial plus stratified	0.317
10.	Initial plus smooth stratified	0.323

The best (lowest) score is achieved when both the initial (0400 LST) precipitation and stratified map type is considered. The best single predictor is the initial precipitation category; that is, conditional climatology with a score of 0.385. If the initial condition is not known, the stratified types and the smooth stratified types yield the best score.

9. REMARKS

Although there is evidence that probability estimates based on map types generated after the data are stratified, according to subsequent weather category are better; that is, result in lower "P" scores than estimates based on unstratified types prepared for general usage, the statistical significance of the difference in the "P" scores cannot be determined without testing on a large sample of independent data. Since we were unable to obtain a large sample of independent data, we cannot say with any large degree of certainty that stratification is important. Since stratifying reduces the sizes of the sub-samples, a long record of past weather is needed

to provide sufficient predictor and predictand data to generate map types and obtain reliable probability estimates.

Since general map types are generated without regard to subsequent weather category, independent sample testing is less critical. The relative frequencies given in Table 4 are substantial departures from the unconditional relative frequencies given in Table 1. They demonstrate what might be gained in longer range forecasting if accurate prognostic charts of 1000 mb heights were available. The relative frequencies given in Table 5 and the "initial plus general" score of 0.330 in Table 6 indicate that the addition of map type information to conditional climatology tables significantly improves estimates of the probability of future precipitation categories. However, many of the sample sizes in Table 5 are small, resulting in possible large departures between the estimated probabilities and true probabilities.

There is no evidence that smoothing, by averaging a number of similar maps, significantly improves a particular map type.

Acknowledgments

The expert computational support by Eugene A. Bertoni, Air Force Cambridge Research Laboratories, and Arthur Abelowitz and E. Mark Hussey, Analysis and Computer Systems, Inc., is gratefully acknowledged. This study would not have been possible without the grid-point data prepared and supplied by the National Meteorological Center.

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